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United States Patent [19]

Olive

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[45] Date of Patent: Nov. 17, 1992

[54] FLOW REGULATOR DAMPER ELEMENT

[75] Inventor: Peter Olive, Needham, Mass.

[73] Assignee: Infusaid Inc., Norwood, Mass.

[21] Appl. No.: 650,371

[22] Filed: Jan. 30, 1991

[51] Int. Cl.[5] A61M 5/00

[52] U.S. Cl. 604/247; 604/141; 137/504; 128/DIG. 12

[58] Field of Search 604/30, 31, 133, 141, 604/186, 246, 247, 254; 128/DIG. 12; 137/499, 504

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Primary Examiner—C. Fred Rosenbaum
Assistant Examiner—C. Maglione
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas

[57] ABSTRACT

A flow regulator/restrictor placed in a fluid path to passively compensate for variations in fluid pressure by deflection or movement. In one embodiment a silicon micromachined housing has a damper beam cantilevered to the interior wall between inlet and outlet. Deflections of the beam vary the volume of the restrictive gap formed between the damper beam and the interanl wall of the housing adjacent the outlet. In another embodiment the damper element is a floating element in the housing and has conformal side walls with the interior of the housing. The restrictor elements may be stacked to provide a stepped pressure drop, restrictor system.

19 Claims, 2 Drawing Sheets

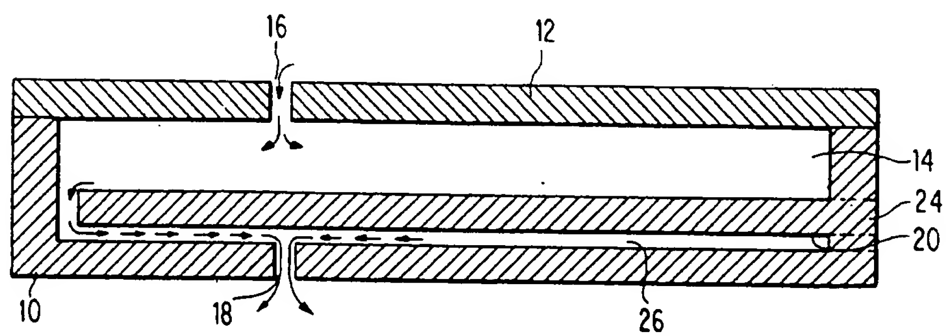


FIG. 1

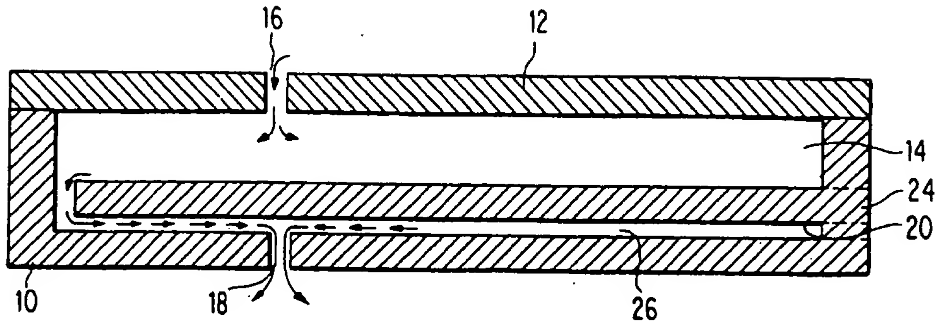


FIG. 2

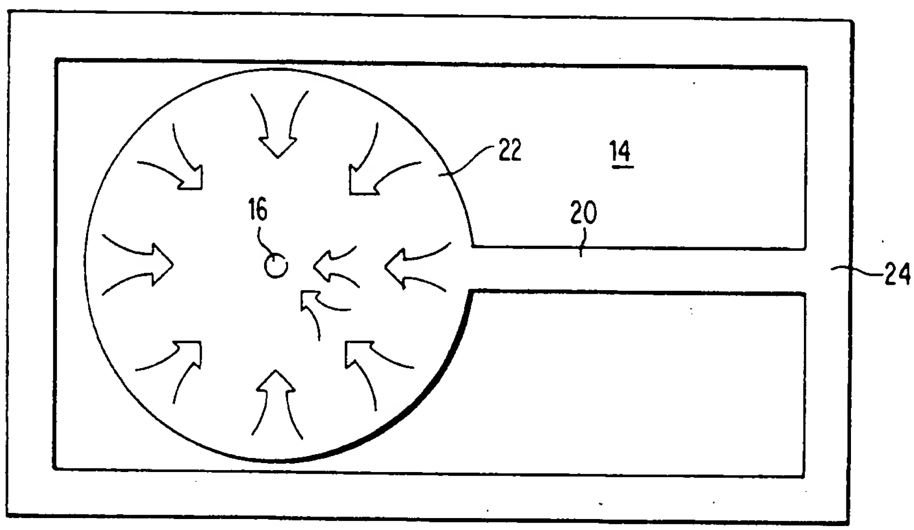


FIG. 3

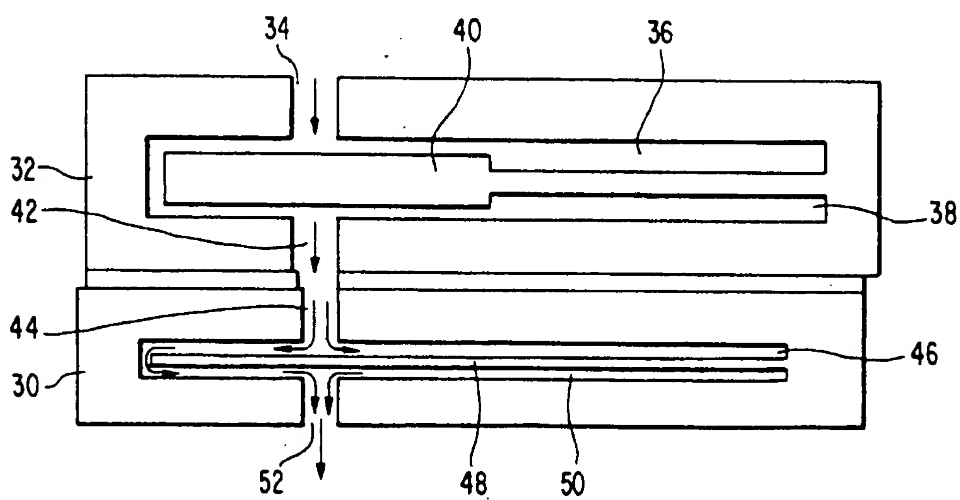
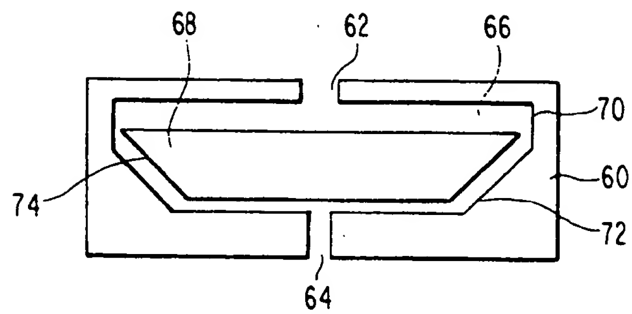


FIG. 4



FLOW REGULATOR DAMPER ELEMENT

BACKGROUND OF THE INVENTION

This invention relates to implantable medication devices and, in particular, to an implantable infusion device arranged to provide a flow of medication into the body. More particularly, this invention is directed to a component of such a device, a flow restrictor and/or regulator for purposes of providing a uniform, that is, constant flow right in the system despite varying external operating pressures.

Medication infusion devices are well known in the art such as the INFUSAID line of devices and a host patented technology as represented by U.S. Pat. Nos. 3,731,681, 4,511,355 and 4,626,244. Those three patents are representative of a host of technology which is directed to implantable devices which provide a relatively constant flow of medication from an implanted dispensing system. In these devices a flexible diaphragm or bellows defines a reservoir housing the medication. A relatively constant pressure is exerted on that diaphragm, for example, by utilizing freon or other vaporizable material to exert a pressure which is above body pressure. The medication is thus forced from the reservoir into a long capillary tube. The tube, by its length, is used as a flow limiting resistance. The medication is delivered to an infusion site at a point remote from the implantation site of the device.

In these fluid delivery systems a flow regulator may be used to provide a steady state output between the pump and the delivery site. Such devices may be accumulators, valved reservoirs and the like. There exists in the art a need to simplify such devices in implantable systems to improve reliability, reduce weight and bulk.

A standing requirement for such systems is compactness and reliability. Additionally, the materials which are used must be compatible with not only the medication which is employed, but also the in-vivo requirements.

Within the prior art various proposals have been made to decrease the size of certain components such as capillary systems utilizing silicon and micro machining concepts.

Reference is made to U.S. Pat. No. 4,537,680 which relates to an integral fluid filter and capillary wherein the capillary is formed by a groove that is etched in the surface of the silicon substrate. Silicon processing is done utilizing conventional semiconductor processing technology. A glass plate is bonded to the surface of the substrate to form a long capillary groove that has a very small cross-sectional area. Also utilizing silicon etching techniques, two comb filters are placed at each end of the capillary groove by defining a series of parallel grooves of smaller cross sectional area.

Reference is also made to U.S. Pat. No. 4,626,244 which describes an integral filter and capillary unit micromachined on a silicon substrate. The geometry of the filter and capillary unit is such that an inlet is positioned relative to a series of parallel filter grooves formed in the surface of the substrate. Medication from the inlet thus passes through the filter grooves and is collected in a series of channels of larger size. Those channels provide a supply of filtered medication to a capillary groove which is a series of reentrant loops formed on the silicon surface. The exit of the capillary channel comprises a series of parallel outlet filter grooves arranged about a central outlet collector area. The medication once passing through the outlet filter grooves to the outlet is supplied directly to the portion of the body under treatment by means of a capillary. Both the '680 and '244 patents thus define basic silicon micromachined comb and capillary systems.

Reference is made to "Normally Close Microvalve and Micropump Fabricated on a Silicon Wafer", M. Esashi et al, Proceedings of the IEEE Micro Electro Mechanical Systems, IEEE Catalog Number 89THO249-3 (1989) pp. 29-34". This article describes the fabrication of a microvalve and micropump on a silicon wafer by employing a silicon diaphragm and a piezoelectric actuator. The microvalve structure used for gas flow control comprises a valve structure mounted on a silicon substrate. An inlet is defined on the substrate with an outlet positioned by a pyrex glass cover. A piezoelectric actuator is employed to shift the silicon which has etched thereon a mesa surface which defines the valve.

While not prior art to this invention an article entitled, "Micromachined Silicon Microvalve", Ohnstein et al, IEEE Micro Electro Mechanical Systems (MEMS) 1990, IEEE Cat. No. 90 CH 2832-4 disclosed an electrostatically activated microvalve using silicon as a substrate having an orifice and a valve member made of a passivated silicon nitride. Electrodes are embedded in the structure to provide contacts for valve actuation. The valve acts as a bistable device between an open and a closed position or as a proportional flow control device as a function of applied voltage. Thus, the device operates as a valve requiring actuation for operation.

Despite such advances in the art of micromachined component structures utilizing silicon, a need still exists for components that have inhibited reducing the size of implantable devices. A reliable flow regulator-restrictor to be used with implantable systems that does not require exterior actuation and a power supply is one such requirement.

SUMMARY OF INVENTION

Given the deficiencies of the prior art, it is an object of this invention to provide for an improved silicon micromachined flow regulator.

Yet another object of this invention is to define a compact, yet reliable, flow restrictor having a minimum number of moving components.

Still another object of this invention is to define a miniaturized flow regulation device that allows for integration of electronics to measure flow rate and external conditions that account for variations therein.

These and other objects of this invention are accomplished by defining a flow restriction device comprising in a first preferred embodiment a miniaturized housing having therein a cantilever beam structure. The beam structure comprises a stem and a flow path restrictor. The stem and restrictor define a damper which is placed in the fluid flow path between an inlet and an outlet in the housing. A flow gap is defined between the damper structure and the housing to restrict flow but also provide a pressure differential between the two faces of the damper beam. The pressure difference causes deflection and thus varies the flow gap between the outlet defined in the housing and the lower surface of the damper beam.

If the pressure is fixed for the inlet and outlet, then the flow around the damper beam would be constant. If, however, inlet pressure increases and the flow around

the damper tends to increase causing a pressure difference across the beam. The pressure would be greater on top of the beam closer to the inlet then on the underside. Thus, the beam would deflect toward the outlet and decrease the flow through the restrictor. Thus, compensation for higher pressure gradients occurs by restricting the flow path. The converse occurs if the inlet pressure decreases which causes the flow gap to widen.

Sensitivity of the system can be enhanced by providing flow restrictors in a series arrangement each having different damper geometries. Additionally, since the devices can be manufactured utilizing silicon micromachining capabilities, it is possible to provide integration of electronics into the devices. For example, a resistance beam can be placed on the damper beam to measure deflection. This provides an accurate measure of flow rate, and therefore, pressure drop. Similarly, a temperature sensing circuit can be placed in the device to provide an indication of temperature variations and thus, correct for variations in viscosity of the fluid passing therethrough.

In a modification of this invention the restrictor element "floats" in a housing without attachment to a wall. The position is determined by pressure differential and either magnetic or electro-static control. By providing lateral flow gaps better dimensional tolerances are obtained in the silicon etching process.

This invention will be described in greater detail by referring to the attached drawing and the description of the preferred embodiments that follow.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a side view of a first preferred embodiment of this invention;

FIG. 2 is a plan view of the first embodiment of this invention;

FIG. 3 is a side view of a second preferred embodiment of this invention; and

FIG. 4 is a side view of a third preferred embodiment of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, a first preferred embodiment of this invention is depicted In this embodiment, a housing **10** is defined by a shallow box-like structure. A top plate **12** may be either integrally formed or placed on top of the box structure **10** to define a chamber **14**. The top **12** has an inlet opening **16**. The housing **10** has an outlet **18** in the lower surface.

A damper beam structure is rigidly attached to the housing **16**. This damper structure comprises a cantilever beam **20** and a damper plate **22**. As illustrated in FIGS. **1** and **2**, the beam structure is cantilevered from the wall **24** and projects within the cavity **16** to a position between the inlet **16** and the outlet **18**. The damper beam structure is positioned within the cavity **14** so that it divides the volume thereof into two components of unequal volume.

The first preferred embodiment of the invention works as follows. Assuming first a fixed inlet and outlet pressure, internal pressure in the housing will be uniform and thus the flow around and under the damper beam **20** and damper plate **22** will be constant. The flow gap **26** which is established between the underside of the damper beam and the base of the housing is narrow, and thus, restricts the flow. Given the differential volume between this flow gap **26** and the remainder of the compartment **14**, a pressure differential is set up across the damper plate **22**. Given the cantilever construction, the plate **22** deflects to equalize the pressure as a function of volume and thus set the flow gap. That is, in order the equalize the pressure, drop across the upper and lower face of the damper plate **22**, deflection of the beam occurs thereby displacing the plate relative to the restrictive gap **26** until equalization occurs by varying the volumes.

If the inlet pressure, shown by arrows at inlet **16**, increases, then the flow around an under the damper plate **22** increases causing a larger pressure drop across the beam structure. This increase in pressure would cause a further deflection of the beam, downward toward the outlet **18**. The volume of the gap **26** decreases thereby adding a restriction to the flow path and decreasing the flow through the restrictor. Thus, compensation for a higher inlet pressure occurs since the higher pressure gradient tends to cause an increased restriction in the flow path. The flow rate through the device then tends to be equal despite having an increase in external operating pressure.

If the pressure at the inlet **16** decreases, then the reduction in flow would tend to decrease the pressure differential across the damper plate **22**. As a result the beam would deflect upward toward the inlet **16** increasing the volume of the flow gap **26**. The flow path would thus become less restrictive and the flow through the outlet **18** would increase. Thus, the change in gap compensates for a change in the operating pressure which tends to make the flow rate through the device constant.

The same compensation effect would occur for changes in outlet pressures. It will be apparent that deflection of the damper plate **22** to equalize the pressure differential will provide flow regulation as a function of a change in pressure at the flow gap **26** as the outlet pressure changes.

Referring now to FIG. **3**, a second preferred embodiment of this invention, is depicted. As is apparent from the preferred embodiment of FIG. **1** a restrictive gap must be maintained across at least one face of the damper beam. However, an increase in the total device restriction can occur by having a restrictive gap on both the top and bottom of the beam. The device, however, will become less sensitive, that is, there would be a decrease change in flow restriction compared to a device having a single gap for the same given change in pressure. To increase sensitivity the single restrictor configuration of FIGS. **1** and **2** can be stacked in a series arrangement to increase the net restriction. Such is illustrated in FIG. **3**. As illustrated, this preferred embodiment comprises a pair of stacked flow regulator elements **30** and **32**. An inlet to the system **34** defines a flow inlet into cavity **36**. A restriction gap **38** is defined therein between the damper beam structure **40** and a first outlet **42**. The damper beam **40** is cantilevered in a manner similar to that illustrated in FIGS. **1** and **2**.

The stacked restrictor then comprises a second unit **30** having its inlet **44** in alignment with the outlet **42**. Fluid flow, as illustrated by the arrows in **43**, is thus delivered into a second chamber **46** having a second damper beam element **48**. A second restriction gap **50** is defined between the damper **48** and the outlet to the system **52**.

As illustrated in FIG. **3**, cavity **46** has a greater internal volume than that of cavity **36**. Likewise, the restrictive gap **38** has a greater volume than that of gap **50**.

The size of the damper beam 40 associated with the first restrictor 32 is larger than that of beam 48 associated with the second restrictor 30.

By adjustment of these volumes and damping characteristics of the cantilever beams the restriction characteristics and thus the flow characteristics for the system can be adjusted. Moreover, by having a stacked arrangement as illustrated in FIG. 3, the restrictive gaps alternate from top to bottom, that is, they are separated by a chamber. Consequently, effects from changing the gravitational field direction are nulled by the system.

Referring now to FIG. 4, a third preferred embodiment of this invention is depicted. This preferred embodiment departs from the previous two in that the flow regulator element is not coupled, that is, structurally tied to the housing. In FIG. 4, a housing, 60, made of silicon or a material capable of micromachining has an inlet 62 and an outlet 64. A cavity 66 is formed in the housing 60. Formation of the inlet 62, outlet 64 and cavity 66 can be done using conventional silicon etch techniques. While illustrated as a single unit, in cross section, it is apparent that the unit can also be made by fashioning a two place housing similar to that of FIG. 1 with a body and a top cover plate. As illustrated in FIG. 4, the cavity 66 is formed by an internal circumferential vertical side 70 and a tapered or conical side section 72. Because etch rates can be controlled and generally form tapered side walls, silicon processing allows the formation of this internal cavity diameter utilizing well established techniques.

The flow restrictor element 68 is a truncated cone having sides 74 which are conformal with the wall 72 of the cavity 66. The restrictor 68 is preferentially made of a silicon material having embedded therein conductive particles or the like. The particles which are used are a function of the type of suspension used for the flow restrictor element 68. For example, magnetic suspension can be used to position element 68 inside the cavity 66 and thus control flow rate between inlet 62 and outlet 64. If a magnetic suspension system is used then fairest particles would be embedded in the restrictor element 68. By application of an external field the positioning of the element 68 can be maintained relative to the inlet 62 and outlet 64.

An alternative technique of positioning could be by electro static suspension and/or control. Again, conventional techniques for actuation of piezoelectric elements can be employed in the context of this flow regulator device.

As is apparent from FIG. 4 the restrictor channel is defined as a function of the space which exists between the lateral walls of the restrictor element 68 and the boundary walls of the channel 66. Given the truncated conical design a more accurate micromachining by controlling the preferential etch allows for the definition of a restrictor geometry having greater precision.

As is apparent to one of working skill in this technology the devices illustrated in FIGS. 1-4 require fine geometry and close tolerances. They can be fashioned from a variety of materials. However, utilizing silicon and silicon micromachining is preferred. These processes, consistent with accepted technology in the manufacture of semiconductor devices allow for required tolerances to be maintained yet the process is economical for large scale production. The use of semiconductor processing to manufacture these flow devices is recognized in the art. For example, patterning can be done by employing silicon oxide grown on the surface of a monocrystalline silicon substrate to create an accurately position to the flow outlet. By utilizing standard photolithography and etching processes with appropriate mask patterning the device can be built using techniques which are well known in semiconductor processing.

For further reference, the disclosures in U.S. Pat. Nos. 4,537,680, 4,626,244 and an article by Angell, "Silicon Micromechanical Devices", Scientific American, April 1983, pp. 44-55" provide details. One of working skill would use semiconductor processing technology to the silicon embodiments of this invention by employing well known processing techniques.

By utilizing silicon as a material of choice for these flow restrictors additional advantages accrue. For example, electronics could be integrated onto the devices for purposes of test and monitoring. Measurement of the deflection of the damper beams can be accomplished by utilizing a resistance bridge that employs a strain gauge. Measurement of beam deflection provides a measure of flow rate and thus pressure drop across the system. Similarly, utilizing the same electronics a temperature sensing circuit can be placed on the device to provide an indication of in-vivo temperature and thus correct for changes in viscosity of the fluid which is passing through the system.

It is apparent that further changes and modifications to this invention may be made without departing from the essential scope thereof. For example, in the case of the FIG. 1 cantilever configuration a multi-point web support could be used. The restrictor would flex on the web in response to pressure deviations.

Having defined my invention, I claim:

1. A device placed in a fluid flow to equalize pressure between an inlet and an outlet comprising:
   - a housing, said housing having a fluid inlet, a fluid outlet and a chamber therebetween;
   - a unitary silicon damper beam in said chamber, said damper beam affixed to said housing and dividing said chamber into two regions, one of said regions defining a restrictive gap between said damper beam and said fluid outlet,
   - wherein variations in pressure between said fluid inlet and said fluid outlet are compensated by deflection of said damper beam to vary the volume of said restrictive gap and thereby provide a compensated flow at said outlet.

2. The device of claim 1 wherein said damper beam comprises a cantilevered beam attached at one end to said housing and having at the opposite end a plate member positioned between said fluid inlet and said fluid outlet.

3. The device of claim 2 wherein said fluid inlet and said fluid outlet are positioned on said housing in alignment with each other and wherein said plate is symmetrical to said alignment of said fluid inlet and fluid outlet.

4. The device of claim 1 further comprising electronic means positioned on said damper beam to provide an output representative of beam deflection.

5. The device of claim 1 wherein said housing comprising a housing body and a cover member, said housing body and said damper beam comprising an integral silicon structure.

6. The device or claim 5 further comprising electronic means on said housing to determine in-vivo temperature of said device.

7. The device of claim 1 further comprising a second housing, said second housing having a fluid inlet posi-

tioned in fluid communication with said fluid outlet of said housing; said second housing having a fluid outlet and a chamber between said fluid inlet and said fluid outlet of said second chamber,

a damper beam positioned in the said second housing's chamber and dividing it into two regions, one region defining a restrictive gap in said second housing between said damper beam therein and the fluid outlet of said second housing, wherein variations in pressure in said fluid flow between said inlet in said housing and said fluid outlet of said second housing are compensated by deflections of the respective damper beams.

8. A device placed in a fluid flow to equalize pressure between an inlet and an outlet comprising:

a first housing, said first housing having a fluid inlet, a fluid outlet and a chamber therebetween;

a unit damper beam in said chamber, said damper beam affixed to said housing and dividing said chamber into two regions, one of said regions defining a restrictive gap between said damper beam and said fluid outlet,

wherein variations in pressure between said fluid inlet and said fluid outlet are compensated by deflection of said damper beam to vary the volume of said restrictive gap and thereby provide a compensated flow at said outlet;

a second housing, said second housing having a fluid inlet positioned in fluid communication with said fluid outlet of said first housing; said second housing having a fluid outlet and a chamber between said fluid inlet and said fluid outlet of said second housing,

a damper beam positioned in the said second housing's chamber and dividing it into two regions, one region defining a restrictive gap in said second housing between said damper beam therein and the fluid outlet of said second housing, wherein variations in pressure in said fluid flow between said inlet in said housing and said fluid outlet of said second housing are compensated by deflections of the respective damper beams.

9. The device of claim 8 wherein said damper beam in said housing has a different geometry than the damper beam in said second housing.

10. The device of claim 8 wherein said chamber of said housing has a volume which is different than the volume of the chamber in said second housing.

11. An implantable medication device comprising;

a reservoir having a supply of medication, means to urge said medication out of said reservoir;

a capillary in fluid communication with said reservoir receiving said medication and delivering it to a treatment site;

a flow regulator placed between said reservoir and said capillary to passively equalize fluid pressure of medication to said capillary, said flow regulator comprising;

a housing, said housing comprising a housing body and a cover member and having an inlet in fluid communication with said reservoir, a fluid outlet in communication with said capillary and a chamber between said fluid inlet and said fluid outlet;

a damper element in said chamber, said damper element dividing said chamber into two regions, one of which defining a restrictive gap between said damper beam and said fluid outlet, said housing body and said damper element comprising an integral silicon structure wherein variations in pressure between said fluid inlet and said fluid outlet are compensated by movement of said damper element to vary the volume of said restrictive gap and thereby provide a compensated flow to said outlet.

12. The device of claim 11 wherein said damper element comprises a cantilevered beam attached to said housing at one end and having at the opposite end a plate member positioned between said fluid inlet and said fluid outlet.

13. The device of claim 12 wherein said fluid inlet and said fluid outlet are positioned on said housing in alignment with each other and wherein said plate is symmetrical to said alignment of said fluid inlet and fluid outlet.

14. The device of claim 14 further comprising electronic means on said housing to determine in-vivo temperature of said device.

15. An implantable medication device comprising;

a reservoir having a supply of medication, means to urge said medication out of said reservoir;

a capillary in fluid communication with said reservoir receiving said medication and delivering it to a treatment site;

a flow regulator placed between said reservoir and said capillary to passively equalize fluid pressure of medication to said capillary, said flow regulator comprising;

a housing, said housing having an inlet in fluid communication with said reservoir, a fluid outlet in communication with said capillary and a chamber between said fluid inlet and said fluid outlet;

a damper element in said chamber, said damper element dividing said chamber into two regions and comprising, a unitary silicon member placed in said chamber and not mounted to an internal wall.

16. The device of claim 15 further comprising electronic means positioned on said damper element to provide an output representative of element deflection.

17. An implantable medication device comprising;

a reservoir having a supply of medication, means to urge said medication out of said reservoir;

a capillary in fluid communication with said reservoir receiving said medication and delivering it to a treatment site;

a flow regulator placed between said reservoir and said capillary to passively equalize fluid pressure of medication to said capillary, said flow regulator comprising;

a housing, said housing having an inlet in fluid communication with said reservoir, a fluid outlet in communication with said capillary and a chamber between said fluid inlet and said fluid outlet;

a damper element in said chamber, said damper element dividing said chamber into two regions, one of which defining a restrictive gap between said damper beam and said fluid outlet, wherein variations in pressure between said fluid inlet and said fluid outlet are compensated by movement of said damper element to vary the volume of said restrictive gap and thereby provide a compensated flow to said outlet,

a second housing, said second housing having a fluid inlet positioned in fluid communication with said fluid outlet of said housing; said second housing having a fluid outlet and a chamber between said fluid inlet and said fluid outlet of said second housing,

a damper beam positioned in the said second housing's chamber and dividing it into two regions, one region defining a restrictive gap in said second housing between said damper beam therein and the fluid outlet of said second housing, wherein variations in pressure in said fluid flow between said inlet in said housing and said fluid outlet of said second housing are compensated by deflections of the respective damper beams.

18. The device of claim **17** wherein said damper element in said housing has a different geometry than the damper beam in said second housing.

19. The device of claim **17** wherein said chamber of said housing has a volume which is different than the volume of the chamber in said second housing.

* * * * *

United States Patent [19]

Bron

[11] **4,428,397**

[45] **Jan. 31, 1984**

[54] **FLUID FLOW CONTROL DEVICE**

[76] Inventor: **Dan Bron**, 36 Palmach Str., Haifa, Israel

[21] Appl. No.: **408,161**

[22] Filed: **Aug. 16, 1982**

Related U.S. Application Data

[63] Continuation of Ser. No. 842,168, Oct. 14, 1977, abandoned.

[30] **Foreign Application Priority Data**

Oct. 27, 1976 [IL] Israel 50771

[51] **Int. Cl.**³ **G05D 7/01**

[52] **U.S. Cl.** **137/504**; 137/501; 239/542

[58] **Field of Search** 137/501, 504; 239/542

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Primary Examiner—Robert G. Nilson
Attorney, Agent, or Firm—Lane, Aitken & Kananen

[57] **ABSTRACT**

There is provided a fluid flow-rate control device comprising a housing, an elastic stretchable membrane dividing the interior of said housing into a first and a second chamber; an inlet port of said housing leading to a fluid source and communicating with said first chamber; and an outlet port of said housing communicating with said second chamber; wherein the first and second chambers are in fluid communication via at least one passageway the dimensions of which remain unchanged during operation, and said membrane is fixedly held and positioned between said chambers so that when said membrane is exposed to a fluid pressure differential, it is adapted to be stretched and a portion thereof to move, solely by virtue of its elasticity, between positions closer to said outlet port to restrict the rate of flow therethrough, and positions further away from said outlet port to increase the rate of fluid flow therethrough, whereby the flow of fluid through said outlet port is controlled at a constant rate by said membrane, despite variations in the fluid pressure at, at least, one of the ports.

4 Claims, 5 Drawing Figures

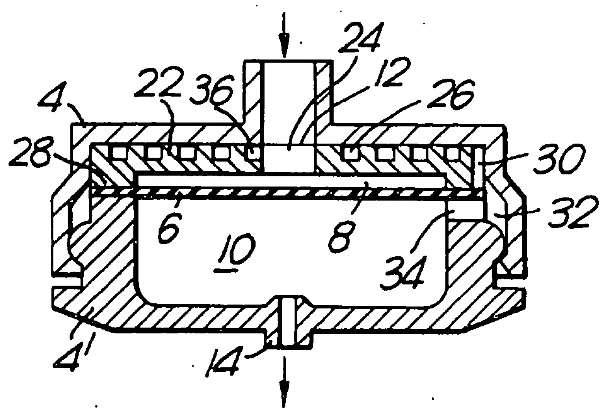


Fig.1.

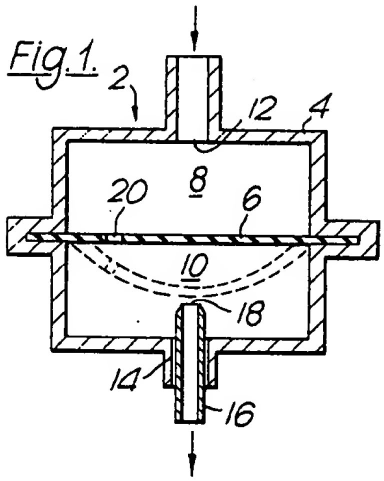


Fig.4.

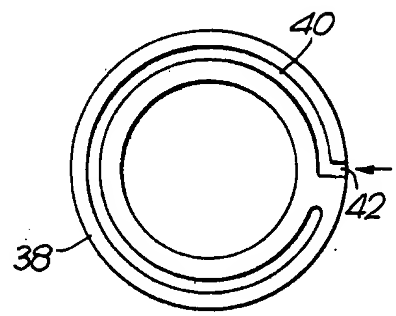


Fig.2.

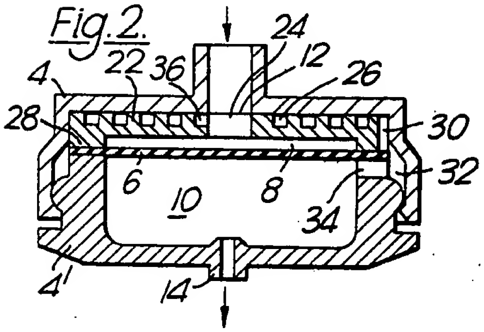


Fig.5.

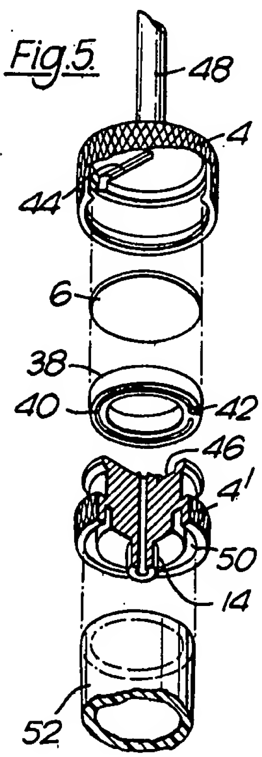
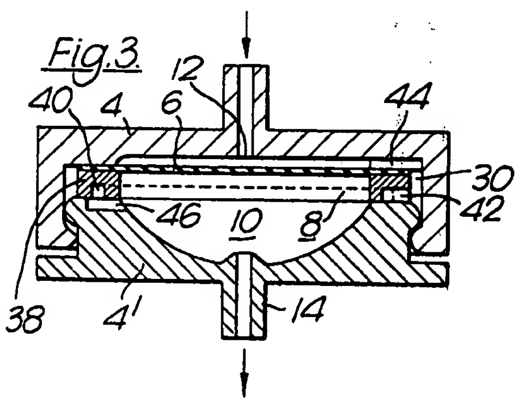


Fig.3.



FLUID FLOW CONTROL DEVICE

This application is a continuation, of application Ser. No. 842,168, filed Oct. 14, 1977, now abandoned.

The present invention relates to a fluid flow control device and more particularly to a fluid flow-rate control device adapted to be connected to a source of fluid under pressure and to provide an output flow of fluid at a controlled constant rate despite variations in the fluid pressure at the source or at the fluid line downstream of the device.

Various types of constant flow regulators are known in the art. For example U.S. Pat. No. 3,357,448 discloses, a valve consisting of a casing having inlet and outlet ports, an apertured plate forming an orifice fixed across the outlet port and a diaphragm mounted in the casing and separating the inlet and outlet ports. The diaphragm carries a block with a central cone adapted to cooperate with the orifice to limit the flow therethrough.

Upon the movement of the diaphragm the block acts against the force of a spring biasing said block away from the orifice to vary the effective area of the orifice as a result of the position assumed by said cone. Between said diaphragm and the inlet port there is provided an apertured retaining plate. Thus as it can be gathered, the control of the fluid flow in a given device is regulated by the properties of the spring which functions to bias the block away from the apertured plate of the outlet port.

Another similar type of a flow regulator is shown in U.S. Pat. No. 3,886,968 which has a diaphragm means mounted in a casing having an inlet and outlet port, said diaphragm means including a flexible outer portion and a thickened central portion adapted to move against the force of a coiled compression spring which is interposed between said thickened portion and the casing portion surrounding the outlet port.

Here again, the diaphragm is merely adapted to divide the interior of the casing into two chambers and to allow the thickened portion thereof to move in relation to the outlet port against the force of a spring which biases said thickened portion away from the outlet port.

In contradistinction to these prior art devices the present invention provides a fluid flow-rate control device comprising:

a housing;

an elastic stretchable membrane dividing the interior of said housing into a first and a second chamber;

an inlet port of said housing leading to a fluid source and communicating with said first chamber; and

an outlet port of said housing communicating with said second chamber; wherein said first and second chambers are in fluid communication via at least one passageway the dimensions of which remain unchanged during operation and said membrane is fixedly held and positioned between said chambers so that when said membrane is exposed to a fluid pressure differential, it is adapted to be stretched and a portion thereof to move, solely by virtue of its elasticity, between positions closer to said outlet port to restrict the rate of flow therethrough, and positions further away from said outlet port to increase the rate of fluid flow therethrough,

whereby the flow of fluid through said outlet port is controlled at a constant rate by said membrane, despite variations in the fluid pressure at, at least, one of the ports.

Accordingly, as it can be recognized, the present invention utilizes the stretchability properties of a membrane, portions of which are adapted to move solely by virtue of the elasticity and stretchability of said membrane in relation to the outlet port to maintain the outlet flow at a constant rate despite variations in the fluid pressure at, at least one of its ports.

Thus, the fluid control device of the present invention represents an improvement over the known prior art devices in its simplicity of construction by avoiding the necessity of utilizing a multiplicity of specially designed shaped valve ports as well as eliminating the need for the intricate assembly of such ports. Furthermore, the dependence of the control of the fluid flow solely on the properties of an elastic membrane provides a more sensitive control device and avoides such adverse effects as hysteresis of a spring which spring has been used in the prior art devices to act as the reference element.

While the invention will now be described in connection with certain preferred embodiments, it will be understood that it is not intended to limit the invention to these particular embodiments. On the contrary, it is intended to cover all alternatives, modifications and equivalent arrangements as may be included within the scope of the invention as defined by the appended claims. Nevertheless it is believed that embodiments of the invention will be more fully understood from a consideration of the following illustrative description read in conjunction with the accompanying drawings, in which:

FIG. 1 is a cross-sectional view of a flow-rate control device according to the present invention;

FIG. 2 is a cross-sectional view of another embodiment of a flow control device according to the present invention;

FIG. 3 is a cross-sectional view of still a further embodiment of a device according to the invention;

FIG. 4 is a plane view of the flow restricting means shown in cross-section in FIG. 3; and

FIG. 5 is an exploded isometric view of a regulated flow-rate infusion device similar to the device of FIG. 3.

In FIG. 1 there is shown a fluid flow control device 2 including a circular or cylindrical housing 4 the interior of which is divided by means of an elastic stretchable disc shaped membrane 6, e.g. a rubber membrane, into a first chamber 8 and a second chamber 10. The first chamber 8 communicates with an inlet port 12 and the second chamber 10 communicates with an outlet port 14. Advantageously, the outlet port 14 is optionally provided with a tubular fitting 16 slidably or threadably engaging said outlet port thereby facilitating the adjustment of the distance of the outlet opening 18 of the fitting from the membrane 6, when in rest position. A throughgoing passageway 20 is made in the membrane 6 at a location displaced from a line passing through the inlet and outlet ports.

In operation, as fluid under pressure enters the inlet port 12, it will flow into chamber 8 and via passageway 20 into chamber 10 and out through the outlet opening 18. As long as the rate of fluid flow is less than a predetermined desired value, the membrane 6 will not be stretched at all or will be only very slightly stretched in the direction of the outlet port. When the flow in the inlet port increases and approaches a desired value as determined by the parameter of the device, a pressure differential, on both sides of the membrane between the

first inlet chamber and the second outlet chamber, is established in accordance with the pressure drop which is caused when the fluid passes through the passageway 20. The dimensions of the passageway remain constant and unchanged during operation. This force differential causes the membrane to further stretch in the direction of the outlet port until, at a predetermined input flow-rate, a portion of the membrane reaches the vicinity of the outlet opening and restricts the same thus preventing further increase in the flow-rate therethrough. The elastic strength of the membrane and its distance from the outlet opening determine the pressure differential thereon and a given size of a passageway, determines the fluid flow-rate therethrough. Conversely, by employing in a control device of fixed parameters membranes having different elastic properties, it is possible to obtain different values of the rate of the output flow. Hence, when it is desired to vary the flow-rate of the device of FIG. 1, the tubular fitting 16 is axially displaced to reposition opening 18 in relation to the membrane 6. This repositioning of the opening 18 changes the required pressure differential which is necessary to stretch the membrane to the newly displaced position of the opening and consequently, also correspondingly changes the rate of the output flow.

In FIG. 2 there is illustrated a constant fluid flow control device especially adapted for small discharge flow rates. The device comprises two interlocking housing parts 4 and 4', an inlet port 12 made in the housing part 4 and an outlet port 14 made in the housing part 4'. The device also includes a flow restricting member 22 for permitting a controlled drip or trickle flow therethrough. Member 22 is held against the inner surface of the housing part 4 and is provided with an opening 24 at its middle portion and a spirally extending channel 26 on its upper surface. The member 22 is further provided with a short peripheral flange 28 adapted to cooperate with the upper edge of the housing part 4' for holding therebetween the peripheral edge of the membrane 6. Instead of the passageway made in the membrane 6 itself, as in the embodiment of FIG. 1, according to this embodiment the passageway providing a communication path between the chambers 8 and 10 is formed in and by the walls of the housing ports around the membrane. The passageway consists of a first section 30 extending between a lateral edge of the member 22 and the inner wall of housing part 4, a second section 32 consisting of a peripheral cavity formed by said housing part and of a third section 34 extending between the housing part 4' and a surface of the membrane.

The fluid entering the inlet port 12 passes through the opening 24 and impinges on the membrane 6. Thereafter the fluid enters the flow restricting channel 26 at 36, flows along the channel to exit the latter at passageway section 30 and continues therefrom via passageway sections 32 and 34 into chamber 10. Depending on the fluid pressure differential which is thus established on both sides of the membrane, the latter will stretch in the direction of the outlet port 14 to restrict the flow therethrough thus operating the device in a manner similar to that described hereinbefore with reference to the device of FIG. 1.

It whould be noted that instead of providing the flow restricting channel 26 on the upper surface of member 22, such a restricting channel can just as well be provided on the bott m surface of the member r in a protruding peripheral portion f the housing part 4, in which cases the channel will be covered by the upper surface of only a portion of the membrane 6. Similar restricting channel arrangements may, of course, be formed in the housing part 4'. Also, a restricting channel can be formed in the walls of the housing and may be constituted by a labyrinth-like path as known per-se in the art.

Turning now to FIGS. 3 and 4, there is shown an adjustable fluid flow-rate control device having a ring-like fluid flow restricting member 38. As best seen in FIG. 4, on one side of the member 38 there is made a channel 40 having an inlet 42 extending to the periphery of the member while the other end of the channel terminates short of said inlet 42. The member 38 is held between the bottom part of the housing and the membrane 6 which, in turn, is peripherally engaged by the upper part of the housing.

The fluid entering the inlet port 12 into chamber 8 can pass through a first section 44 of the passageway extending in the wall of the upper part of the housing 4 and therefrom around the membrane 6 into a second section 30 of the passageway. Section 30 communicates with the inlet 42 of the member 38, thus the fluid entering said inlet circulates in the channel 40 and is adapted to exit therefrom at the third passageway section 46 made in the housing part 4' which latter section leads to chamber 10. Naturally, the member 38 may also be positioned with its channel 40 facing the housing part 4', in which case the passageway section 46 will be formed in the housing part 4. As the housing part 4' is adapted to be axially rotated in respect to housing part 4 and with respect to the member 38, the passageway section 46 may be rotatatly aligned with any point along the channel 40. This alignment establishes the effective length of the restricting channel or in other words, establishes the effective resistance to the fluid flow through the passageway. As the effective length of the restrictive channel is decreased, the resistance to flow decreases and an initial preset regulation of the flow is achieved by the adjustment of the resistance of the passageway to the flow of fluid, whereafter the flow rate is controlled at a constant rate by said membrane.

In FIG. 5 there is illustrated in an exploded view, a flow-rate regulating device similar to the device of FIG. 3 but especially adapted for use as a regulated flow-rate infusion device. The various structural parts corresponding to the parts shown in FIGS. 3 and 4 are therefor marked with the same numerals. As seen in the figure, to the housing part 4 there is integrally affixed, a connecting tube 48 while the housing part 4' is provided with an annular groove 50 which is adapted to hold a transparent drip chamber 52 (only a section of which is shown), inserted therein.

As explained hereinbefore, by rotating housing part 4' with respect to housing part 4, the passageway section 46 is positioned along the restricting channel 40 to thereby determine the effective length of the channel through which the fluid must pass from the inlet 42 to communicate with the chamber 10. When the inlet 42 is aligned with the passageway section 46, the restricting channel is by-passed and there is established a direct flow through said passageway.

While particular embodiments of the invention have been described and shown with reference to the figures it will be evident to those skilled in the art that the present invention may be emb died in other specific forms without departing from the essential characteristics thereof. The present emb diments are therefore to

be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A fluid flow-rate control device comprising:

a housing having two interlocking parts;

an elastic stretchable membrane clamped along its periphery, inside the housing, between the two interlocking parts, said membrane dividing the interior of said housing into a first chamber and a second chamber;

an inlet port of said housing leading from a fluid source and communicating solely with said first chamber; and

an outlet port of said housing communicating with said second chamber;

wherein said first and second chambers are in fluid communication via at least one passageway extending in part beyond the periphery of the membrane and along an inner surface of at least one of the parts of the housing and leading from said first chamber to said second chamber, said passageway communicating solely with the first and second chambers and including at least one portion comprising a spirally extending channel in which flow is relatively restricted, the dimensions of the passageway remain unchanged during operation, and said membrane is fixedly held and positioned between said chambers so that when said membrane is exposed to a fluid pressure differential, it is stretched and a portion thereof is moved, solely by virtue of its elasticity, between positions closer to said outlet port to cause said portion of said membrane to restrict the rate of flow through said outlet port, and positions farther away from said outlet port to cause said portion of said membrane to increase the rate of fluid flow through said outlet port,

whereby the flow of fluid through said outlet port is controlled at a constant rate by said membrane, despite variations in the fluid pressure at, at least, one of the ports.

2. The device as claimed in claim 1 wherein a first of the two interlocking housing parts includes the inlet port and the second of the two interlocking housing parts includes the outlet port.

3. The device as claimed in claim 2 wherein said housing parts are adapted to be rotated with respect to each other.

4. The device as claimed in claim 1 wherein said spirally shaped channel is defined in a member dismountably affixed in the housing.

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